LWRS Deliverable M3LW16OR040362

Alkali-Silica Reaction Test Assembly – Report describing the final instrumentation plan of the ASR test assembly

Identification of Mechanisms to Study Alkali-Silica Reaction Effects on Stressed-Confined Concrete Nuclear Thick Structures

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November 25, 2015

Introduction

Three specimens, corresponding to 136 in. - 116 in. - 40 in. (x-axis – y-axis – z-axis) reinforced concrete blocks, will be cast for the purpose of this research project. Two of them will be cast using highly reactive aggregates. The third one will be made of non-reactive aggregates or using reactive aggregates and annealing the alkali-silica reaction by incorporating lithium in the mix. The Alkali-Silica reaction being endothermic, the formation of the silica gel can be accelerated, by maintaining the specimen at a certain temperature. Also for the reaction to occur, excess moisture must exist in the free pore space of the concrete specimen. For these reasons, the three specimens will be housed in an environmentally controlled chamber at a constant heat of 100°F (± 2°F) and relative humidity of 95% (±5%).

This report focuses on the design of a comprehensive instrumentation plan to monitor surface and bulk strains, pressures and internal temperature. The selected sensors are a mix of conventional ones complemented by Optical Fiber Sensing (OFS). Currently, there are two types of OFS: short gauge length (GL = 0.04 in. to 4.0 in.) sensor and long gauge length (GL= 10.0 in. to 390. 0+ in.) sensor. Also, there exist three types of measuring principles in OFS: SOFO (a French acronym for Surveillance d'Ouvrages par Fibres Optiques, i.e., structural monitoring with fiber optics), FBG (Fiber Bragg Grating) and EFPI (Extrinsic Fabry-Perot Interferometry). Based on the literature review, the research team (RT) decided to use long gauge length SOFO in this project for the monitoring of structural deformation. In addition, Distributed Optical Fiber will be embedded in an attempt to capture local damage.

In summary, ten different types of sensors are proposed: DEMEC gauge, surface fiber optic, long gauge length SOFO, embedded KM strain transducer (KM-100B), embedded KM strain transducer integrated with thermocouple (KM-100BT), electrical strain gauge, embedded distributed fiber optic, TPC pressure cell, PROBOX pressure dilatometer, and acoustic emission (AE) sensors. Details on these sensors are discussed later in this report. All embedded sensors have been selected according to the following specifications:

- Documented performance in concrete;
- Long-term reliability of strain/temperature/moisture measurements in concrete;
- High robustness;
- Resistance to alkali/moisture content penetration;
- Corrosion resistance;
- Operating within the operation temperature range;
- Accuracy required;
- Ease of installation;
- Immunity to magnetic interference;
- Price.

Concerning the sensors to measure strains, they have been categorized into three levels:

- Level 1: Manual and mechanical surface measurement and instrumentation;
- Level 2: Local embedded measurement and instrumentation;

- Level 3: Distributed optical fibers sensors.

During the next quarter, RT will pretest all sensors, DAQs as well as the optical fiber coatings in a trial ASR concrete beam at the University of Tennessee Knoxville.

Strain Instrumentation: Level 1 - Surface Strain Measurements

Top surface

Surface concrete strains will be monitored using embedded DEMEC points, to compare with the bulk readings. As expansion progresses, these points are expected to distance themselves from each other. DEMEC gauges will be used periodically to measure this change in distance.

UT Austin used 3/8 in. by 3.5 in. stainless steel bolts casted into the fresh concrete as DEMEC points, as shown in Figure 1. These bolts have a machined DEMEC point at the end. A special drill bit is used to machine these measuring points into each bolt before it is cast into the block.

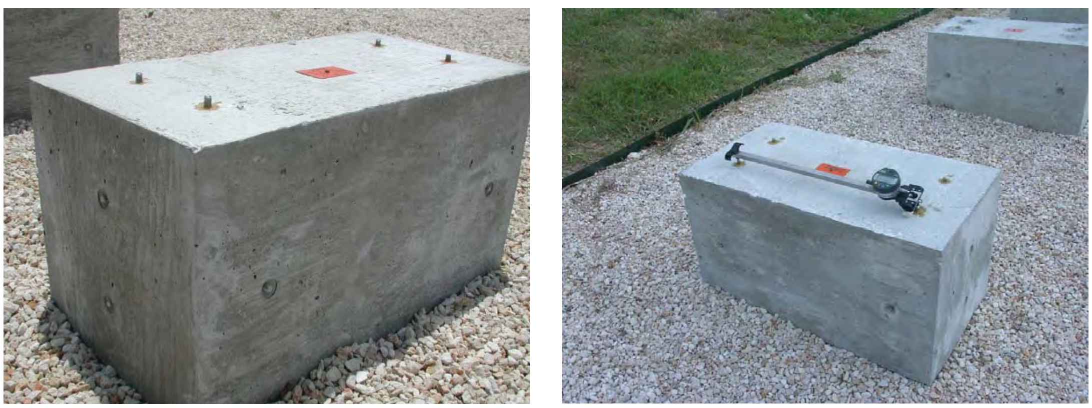


Fig 1: Strain surface monitoring with DEMEC gauges.

DEMEC gages will be used to measure the strain over 4-inch intervals. The intervals can be combined to give results of average strain across the specimen. The close spacing of these DEMEC measuring points will also allow the creation of a system similar to crack indexing.

Another proposed method of measuring top surface strain is to glue optical fibers (OF) to the surface of the concrete specimens. Both of these methods are illustrated in Figure 2. Also, please, refer to T1.1 of Appendix A for more detailed drawings and information on top surface strain measurements.

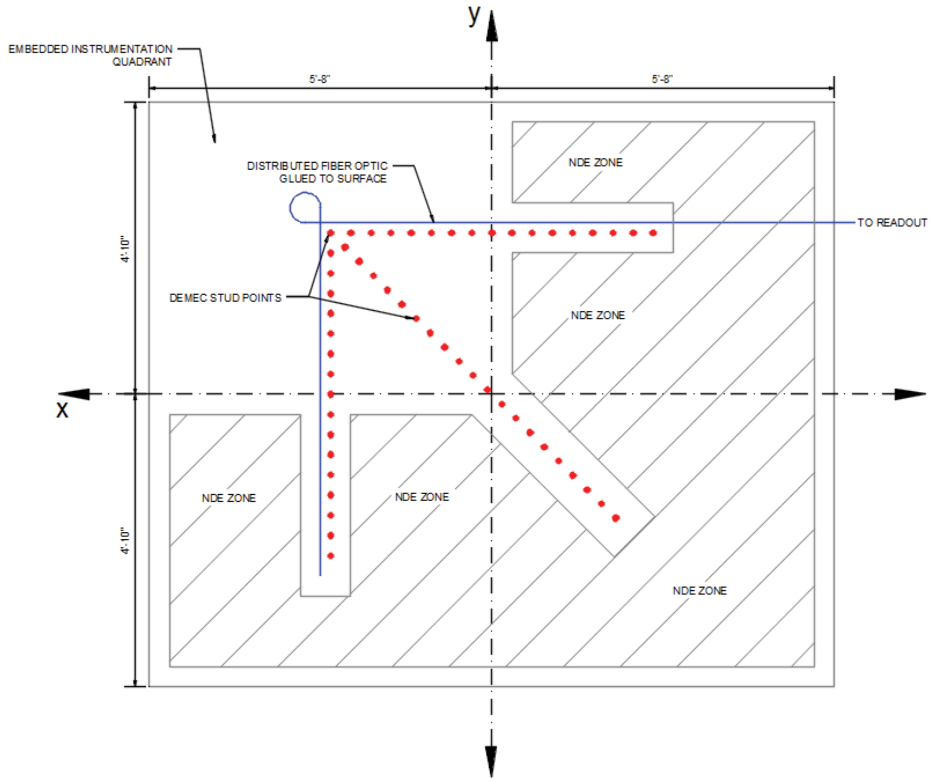


Fig 2: Top surface strain instrumentation.

<u>*Bottom surface*</u>

SOFO sensors (long gauge length - from Roctest Ltd) have been chosen for their high precision and accuracy in measuring deformations when attached to surfaces. SOFO sensors (refer to Appendix C for specifications) having a precision as high as 2 microns will be attached to the bottom surface of the concrete (refer toT1.2 in Appendix A.)

Strain Instrumentation: Level 2 - Embedded Strain Measurements

The embedded instrumentation will be placed on the existing reinforcement bars in near-surface areas, as well as inside the specimen by using additional ties or wires to place sensors in the selected locations. RT will pay attention to the sensors attachments and protections to make sure that these sensors will not be damaged or displaced during the concrete placement and vibration processes.

Because of the double-symmetric design of the concrete specimens, measurement values are estimated to be similar across the axes of symmetry, with the exception of the z-axis which is supposed to exhibit nonsymmetrical expansions due to the dead load of the specimen. To maximize the amount of data collection, embedded instrumentation will be heavily concentrated in one-fourth of the specimen.

Sufficient instrumentation elsewhere in the specimen will be included to confirm or reject the assumptions being made. However, a large number of sensors within and on the concrete specimen will be installed in preparation for the case that measurement values are found not to be symmetrical. These additional sensor nodes are referred to as "Quality Control" in the attached layout drawing T1.3 of Appendix A.

The layout includes embedded strain transducers that are concentrated in the middle of the specimen as that is the anticipated location for the majority of the ASR expansion.

KM-100B sensors, from TML Tokyo Sokki Kenkyujo Co., Ltd. in Japan (Appendix B), have been selected on the basis of their operating temperature range (up to 170°F), cost, and the apparent elastic modulus. So far, 54 KM-100B strain transducers are planned for each specimen. The KM-100B has a gauge length of 4.0 in., which is most appropriate for our aggregate size. Besides, its lower apparent modulus allows the sensor to capture small strains during the early stages of curing. Figures 3 to 5 show the plan and elevation layouts for this embedded instrumentation.

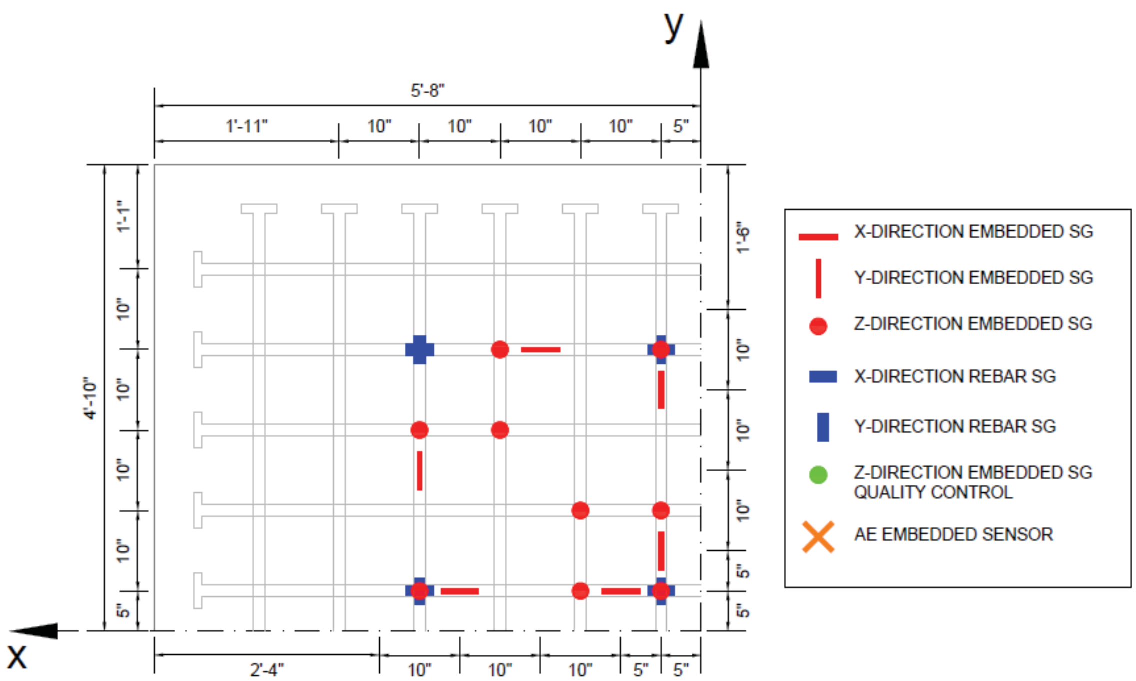


Fig 3: Plan view of embedded instrumentation in quadrant

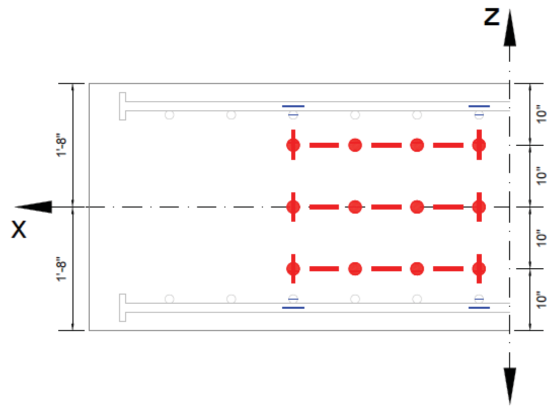


Fig 4: Elevation view of embedded instrumentation in quadrant

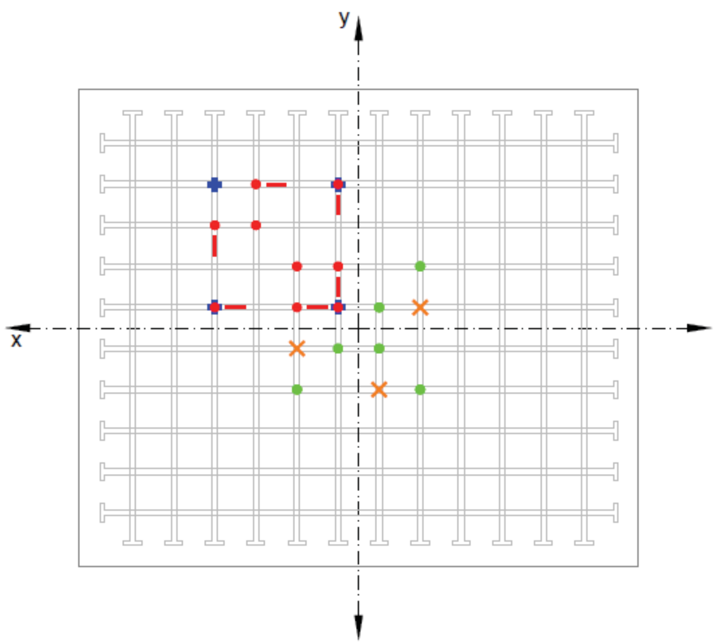


Fig 5: Plan view of embedded instrumentation in entire specimen

The KM-100B sensors will be suspended in the rebar cage with wires before pouring concrete, as illustrated in Figure 6. In order to ensure that no instrumentation is damaged during this process, only select locations between rebar will be open for the pouring. Moreover, pouring the concrete vertically will contribute to limit possible lateral displacement of sensors.

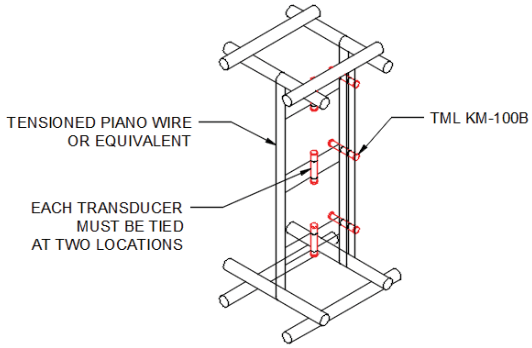


Fig 6: Embedded sensor attachment detail.

Typical electrical strain gages will also be attached to reinforcing bars at specific locations. Reinforcing bars in the selected locations will be cut lengthwise into halves. The strain gages will then be epoxied on the inside of one half of the rebar, and then the rebar will be welding back together. Sheet T1.3- Appendix A shows all embedded sensors layout plans and elevations.

Strain Instrumentation: Level 3 - Embedded Distributed Fiber Optic

Embedded distributed fiber optic (DFO) sensors, with PI (polyimide) coating, have also been selected for this project. They will be tested in the trial beam, as mentioned in the introduction. The corresponding data acquisition system is the LUNA analyzer. It has the capacity for 25 channels. Eight channels for each specimen are being proposed to measure expansion in all coordinate directions. Of the eight channels, four will be devoted to measuring strain in the vertical direction. The remaining four channels will measure strain in the horizontal directions. Of the four horizontal fiber optic strands, two will be placed at an elevation of 10 inches below the top surface of the specimen, and two will be placed at an elevation of 10 inches above the bottom surface of the specimen. The fiber optic strands will be supported by tensioned wire before the pouring of the concrete. See Sheet T4.1 of Appendix A. Figure 7 shows the detailed illustrations of embedded DFO.

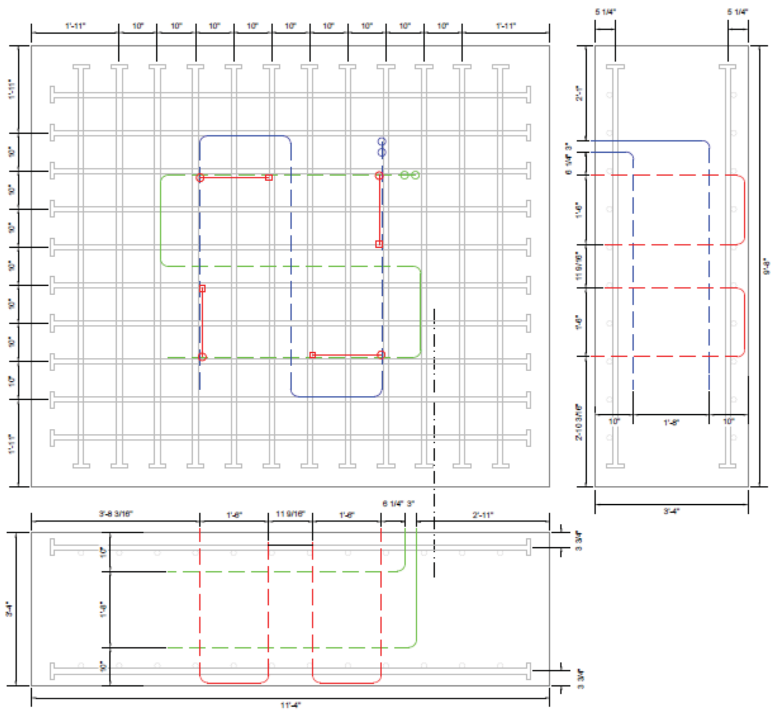


Fig 7: Layout for embedded distributed fiber optic.

Concrete Stress/Pressure Measurements

The Total Pressure Cell (TPC) (Appendix B- TPC datasheet) and Probex dilatometer sensors (Appendix B- Probex datasheet), from Roctest Ltd, are proposed to measure stresses on the concrete/steel frame interface (confined specimen) and internal stresses of the concrete via boreholes, respectively. The TPC is typically used in geotechnical applications to measure stress within or between layers of soil. Their use in the current project will provide data on the pressure being exerted on the confining steel frame by the expanding concrete. Four TPCs will be placed at the interface between the concrete and the confining steel frame. Each TPC will be at the midpoint along each dimension of the specimen as illustrated in T2.1 of Appendix A. Additional TPCs can be placed as needed, as their cost is relatively low in comparison to the other proposed instrumentation.

The Probex dilatometer will be used to determine the modulus of the concrete as the specimens expand. Four boreholes are proposed for each specimen near the corners as illustrated in T2.1 of Appendix A. A single Probex dilatometer can be used in each borehole to determine the modulus of the concrete. The boreholes will require a diameter of three inches and depth of 18 inches in order for the dilatometer to operate.

Embedded Temperature Sensors

Embedded temperature sensors will consist of approximately **9** KM-100BT implemented in each specimen as shown in Sheet T3.1 of Appendix A. The KM-100BT transducers are primarily designed for monitoring strains. Their gauge length is 4.0 in. (refer to Appendix

B– KM datasheet). However, they have an integrated thermocouple that is capable of providing independent temperature data. At each plan location, three transducers will be vertically distributed to provide a temperature gradient varying with elevation.

The purpose of temperature data collection is to ensure that the temperature does not exceed 150°F in order to avoid delayed ettringite formation (DEF). DEF is not desired since the aim is to isolate the sole expansion instigator as ASR.

Non-Destructive Evaluations

Non-Destructive Evaluations (NDE) will be considered in the framework of this project. The proposed layout for the top surface strain instrumentation plan layout allows for space on the surface and within the bulk for NDE techniques and apparatus.

A 16-channel Acoustic Evaluation (AE) data acquisition system will be used for the duration of the project. The channels will be split among the ASR confined, ASR, and control specimens as seven channels, seven channels, and two channels, respectively. Of the seven sensors on each of the two ASR specimens, three will be embedded. Refer to T1.2 and T1.3 Appendix A for the location of AE sensors on the bottom surface and embedded within the specimens.

The size of the AE sensors is approximately 1.0 inch diameter and 1.0 inch height. First, they will be attached to a steel plate. Then, the steel plate with the sensor will be glued to the finished bottom surface of the concrete, after removing the formwork. Adequate space beneath each specimen is considered to comply with the University of Tennessee safety requirements during installation and, when needed, maintenance of AE sensors.

Future Structural Testing

Approximately two years after concrete pouring, the specimens will be cut into beams of roughly 10 in. x 20 in. x 120 in. The aim is to perform several beam tests to assess the effects of ASR expansion on the shear behavior through the three-point bending setups. Instrumentation wiring will be selectively placed to avoid the cutting lines in order to preserve a maximum of sensors for the beam testing. Embedded sensors measuring horizontal strains will be staggered at mid-depth.

Instrumentation Pretesting

A trial beam specimen is being proposed in order to test the application and data collection of the proposed instrumentation. The trial beam specimen will be 10 in. x 14 in. x 48 in. The trial beam is proposed to contain four embedded DFO strands, a KM-100B, a KM-100BT, an array of DEMEC stud points, and two surface attached DFO strands. See attached Appendix D for a detailed illustration of the proposed trial beam.

In order to preliminarily test the durability of embedded sensors in the alkali environment, selected sensors, such as the KM-100B and DFO, will be immersed in a solution of sodium hydroxide after recovery from the trial beam specimen. The reactivity of the submerged instrumentation will be observed. If issues are observed with the reactivity of the instrumentation cabling, alternative cables must be tested before their inclusion in the mock-up ASR specimen is finalized.

Data Acquisition Frequency

Data acquisition frequency will begin shortly after concrete pouring. A relatively high frequent monitoring will start out as high as hourly during the early age curing of the concrete and continue until the completion of the project. However, as the project continues, the frequency will decrease to a minimum of weekly.

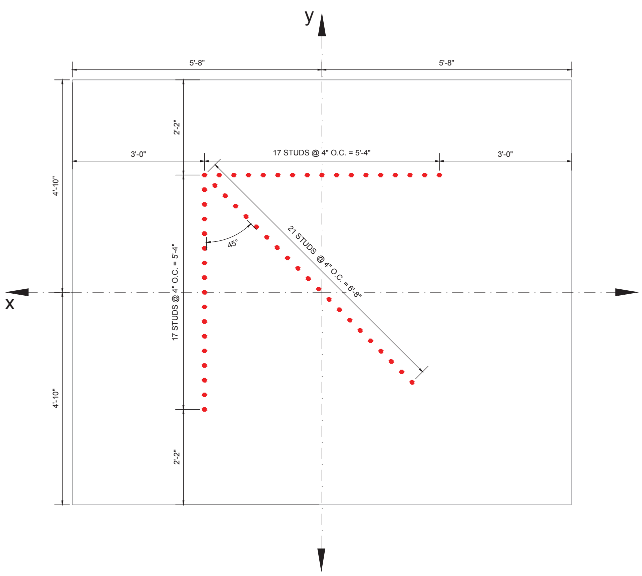
Data Acquisition System

For DEMEC measurements, a specific reading instrument is available at the University of Tennessee (UT) High-bay laboratory. It includes adjustable gauges for measuring 2, 4, 6, 8, or 10 measure points spacing.

KM sensors and electrical strain gages are both based on the Wheatstone bridge circuit. Data from these sensors can be read and recorded by National Instruments (NI) DAQ system, which includes a front terminal block, full, half or quarter bridges input modules, data acquisition and control modules, a module chassis and a management software.

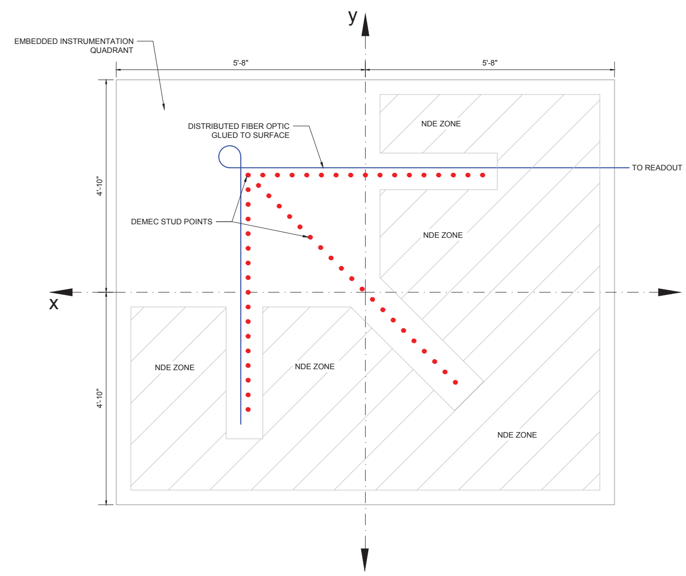
The available NI system at UT has the capability to support KM and strain gage sensors. However, some upgrading is planned in order to allow acquiring hundreds of channel inputs. For instance, front mounting terminal block for universal strain gage input module is needed for KM full bridge channel. Calibration for the existing NI DAQ is needed before testing for obtaining precise output. For a better data management, optimized cable connection architecture or even using wireless communication will be considered in the utilization of NI DAQ.

For all selected fiber optic sensors (except the long gauge length SOFO), a specific LUNA DAQ system, from ONRL, will be utilized. This interrogator can support a maximum of 25 input channels. Each of the other sensors types (long gauge length SOFO, TP cells, Probex dilatometers and AE sensors) requires a specific read unit that can be purchased or rented.



2 | T1.1 — TOP SURFACE STRAIN INSTRUMENTATION LAYOUT

SCALE: 1" = 1'-0"



1 | T1.1 — TOP SURFACE STRAIN INSTRUMENTATION LAYOUT

SCALE: 1" = 1'-0"

NOTES:

- TOP SURFACE INSTRUMENTATION WILL BE THE SAME FOR ALL CONCRETE SPECIMENS.
- A GILSON HM-240 ADJUSTABLE READER WILL BE USED TO MEASURE THE DISPLACEMENT BETWEEN DEMEC STUDPOINTS.

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DRAWN BY: NWH

CHECKED BY:

ASR RESEARCH

TOP SURFACE STRAIN INSTRUMENTATION

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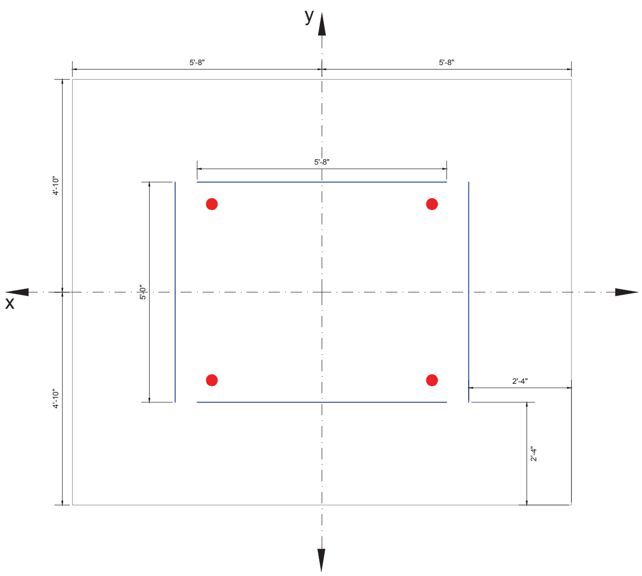
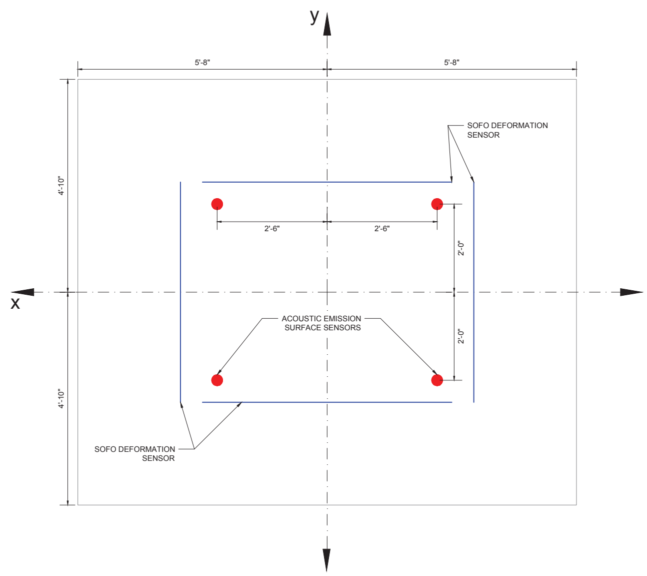
T1.1



2
T1.2
BOTTOM SURFACE STRAIN INSTRUMENTATION - DIMENSIONED LAYOUT
SCALE: 1" = 1'-0"



1
T1.2
BOTTOM SURFACE STRAIN INSTRUMENTATION - GENERAL LAYOUT
SCALE: 1" = 1'-0"

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BOTTOM SURFACE STRAIN INSTRUMENTATION

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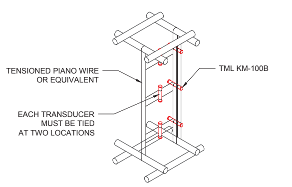
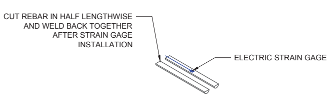
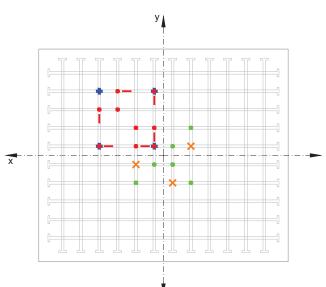
T1.2



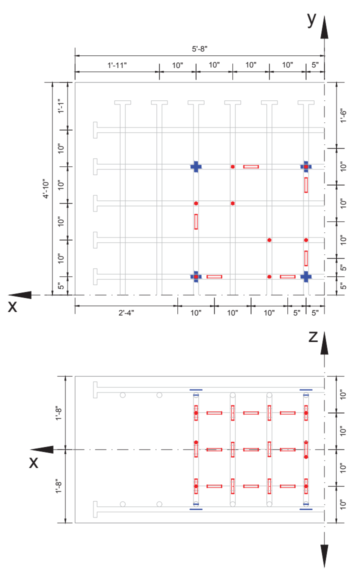
3 / T1.3 ILLUSTRATION OF HANGING EMBEDDED STRAIN GAGES
SCALE: 1" = 1'-0"



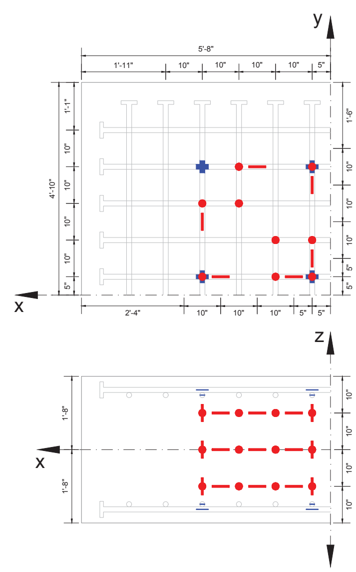
4 / T1.3 ILLUSTRATION OF ATTACHING ELECTRIC STRAIN GAGES
SCALE: 1" = 1'-0"



5 / T1.3 QUALITY CONTROL EMBEDDED SG AND AE EMBEDDED SENSORS
SCALE: 1" = 1'-0"



2 / T1.3 EMBEDDED STRAIN GAUGE SCALED LAYOUT - CONFINED SPECIMEN
SCALE: 1" = 1'-0"



1 / T1.3 EMBEDDED STRAIN GAUGE SYMBOL LAYOUT - CONFINED SPECIMEN
SCALE: 1" = 1'-0"

NOTES:
- "REBAR SG" ARE TO BE STRAIN GAGES APPROPRIATELY ATTACHED TO REINFORCING BARS BY CUTTING REBAR ALONG CENTER AND THEN WELDING BACK TOGETHER AFTER SG INSTALLATION

EMBEDDED INSTRUMENTATION QUANTIITIES	
SENSOR	QUANTIITY PER SPECIMEN
KM-100B	63
REBAR STRAIN GAGE	16

- X-DIRECTION EMBEDDED SG
- Y-DIRECTION EMBEDDED SG
- Z-DIRECTION EMBEDDED SG
- X-DIRECTION REBAR SG
- Y-DIRECTION REBAR SG
- Z-DIRECTION EMBEDDED SG QUALITY CONTROL
- AE EMBEDDED SENSOR

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EMBEDDED STRAIN INSTRUMENTATION

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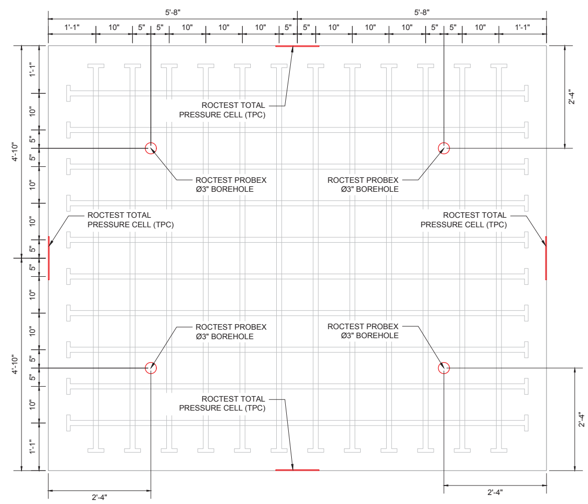

1 / T2.1 STRESS INSTRUMENTATION - PLAN LAYOUT

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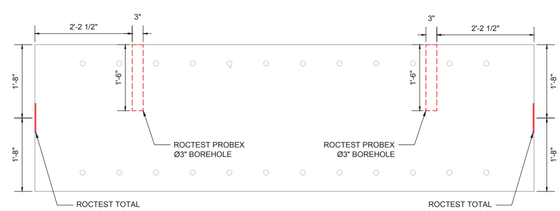

4 / T1.1 STRESS INSTRUMENTATION - ELEVATION LAYOUT

SCALE: 1" = 1'-0"

DESIGNED BY:

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STRESS MEASURING INSTRUMENTATION

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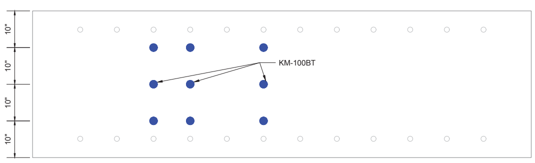
T2.1



2
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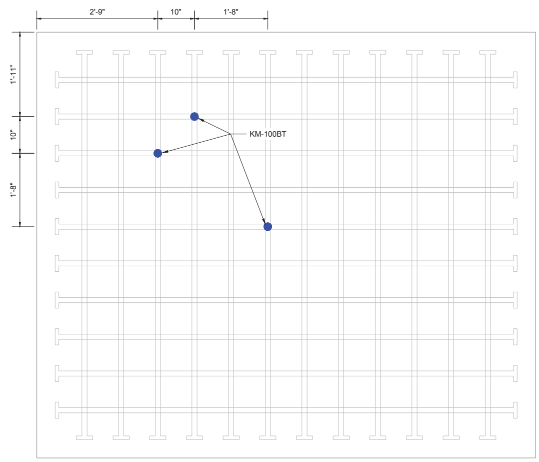

1
T3.1
EMBEDDED TEMPERATURE INSTRUMENTATION - PLAN
SCALE: 1" = 1'-0"

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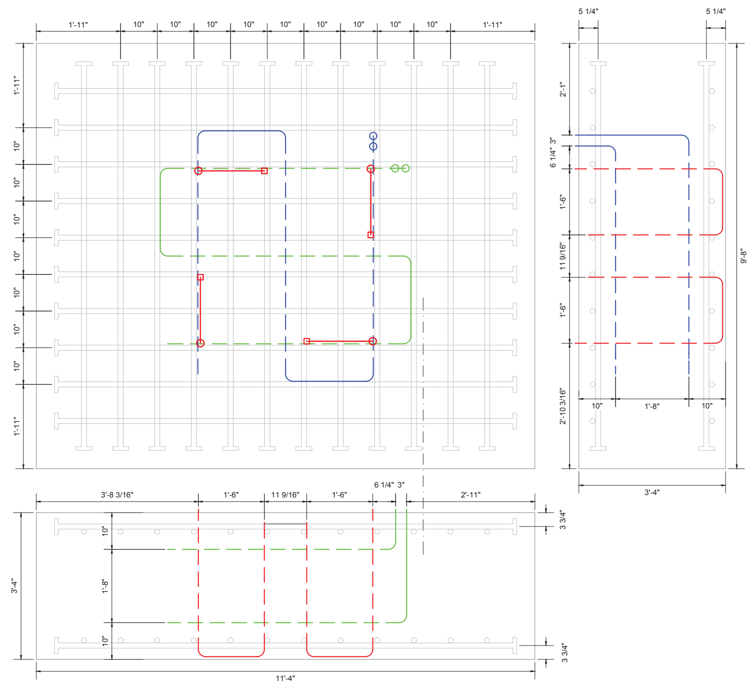

1
T4.1

EMBEDDED DISTRIBUTED FIBER OPTIC LAYOUT
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EMBEDDED DISTRIBUTED FIBER OPTIC

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T4.1

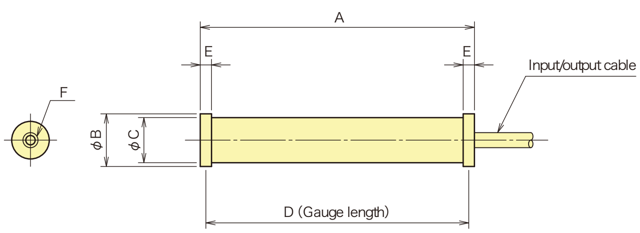
KM Strain Transducer ± 5000× 10^{-6} strain

Protection ratings :
IP 67 equivalent for KM-30
IP 68 equivalent for KM-50F~ KM-200AT

The KM series strain transducers are designed to measure strain in materials such as concrete, synthetic resin which undergo a transition from a compliant state to a hardened state. Their extremely low modulus (40N/mm^2 approx. except for KM-A) and waterproof construction are ideally suited for internal strain measurement during the very early stages of curing. They are totally impervious to moisture absorption, producing excellent stability for long-term strain measurement. Relative temperature measurement is also possible with the KM-A and KM-B. The built-in thermocouple sensor of the KM-AT/KM-BT enable actual temperature measurement in addition to strain measurement. Adding to the above embedment use, surface strain measurement onto concrete, H-beam steel is also available with various optional fittings.

■FEATURES

●Self-temperature compensated transducer having a linear thermal expansion coefficient similar to concrete
●Low elastic modulus enables inner strain measurement during the very early stages of curing
●Simultaneous measurement of strain and temperature except for KM-30 ,KM-50F
●Surface strain measurement is also available onto retaining wall, strut, sheet pile, etc.



Type	Dimensions (mm)						Weight
	A	B	C	D	E	F	(g)
KM-30	34	12	10	31	3	M3 Depth4	12
KM-50F	54	20	17	50	4	M3 Depth6	45
KM-100A KM-100B	104	20	17	100	4	M3 Depth6	75
KM-100HB	104	20	17	100	4	M3 Depth6	80
KM-200A	205	28	23	200	5	M5 Depth8	220
KM-100AT KM-100BT	104	20	17	100	4	M3 Depth6	75
KM-200AT	205	28	23	205	5	M5 Depth8	220

■SPECIFICATIONS

TYPE	KM-30	KM-50F	KM-100A	KM-100B	KM-100HB	KM-200A	KM-100AT	KM-100BT	KM-200AT
Capacity	± 5000× 10^{-6} strain								
Gauge length	31mm	50mm	100mm			200mm	100mm		200mm
Rated output (approxately)	2.5mV/V (5000× 10^{-6})	4mV/V (8000× 10^{-6})	2.5mV/V (5000× 10^{-6})			5mV/V (10000×10^{-6})	2.5mV/V (5000×10^{-6})		5mV/V (10000× 10^{-6})
Non-linearity	1%RO								
Apparent elastic modulus	40N/mm^2		1000N/mm^2	40N/mm^2		1000N/mm^2	1000N/mm^2	40N/mm^2	1000N/mm^2
Integral temperature	–		*1Strain gauges (350Ω Quarter gauge with 3-wire 50×10^{-6} strain/°C approx.				*2Thermocouple T		
Temperature range	−20 ~ +60°C	− 20 ~ + 80°C			−20~+ 180 °C	−20~+80°C			
Input/Output	120Ω Half bridge	350Ω Full bridge							

*1 Relative temperature measurement possible
*2 Real temperature measurement possible

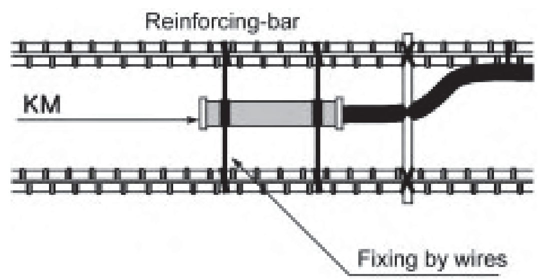
Input/output cable							
	KM-30	φ2.4mm	0.04mm^2	3-core shielded	Vinyl cable	2m	cable-end free
	KM-50F	φ6mm	0.35mm^2	4-core shielded	Chloroprene cable	2m	cable-end free
	KM-100A/-100B	φ9mm	0.3mm^2	5-core shielded	Chloroprene cable	2m	cable-end free
	KM-100HB	φ6mm	0.3mm^2	5-core shielded	Fluoroplastic cable	2m	cable-end free
	KM-200A	φ11.5mm	0.5mm^2	5-core shielded	Chloroprene cable	2m	cable-end free
	KM-100AT/-100BT	φ9mm	0.3mm^2	4-core shielded	T-thermocouple compound cable	2m	cable-end free
	KM-200AT	φ11.5mm	0.5mm^2	4-core shielded	T-thermocouple compound cable	2m	cable-end free

For use of inner strain measurement

The KM Strain Transducers make possible strain measurement in materials such as concrete which undergo a transition from a compliant state to a hardened state. Various strains are produced by external force, ambient temperature, drying shrinkage, materials creep, etc., the KM is designed to measure such strains.
Applicable gauge length should require three times the diameter of the gravel pieces so as to give an averaged evaluation of the concrete.

An installation to reinfocing concrete structures inside

As shown in figure right, attach wires to KM body at 2 points, then position the KM to marked points in advance of reinforcing bar to fix it.



An installation with optional Non-stress meter KMF-51/KMF-52

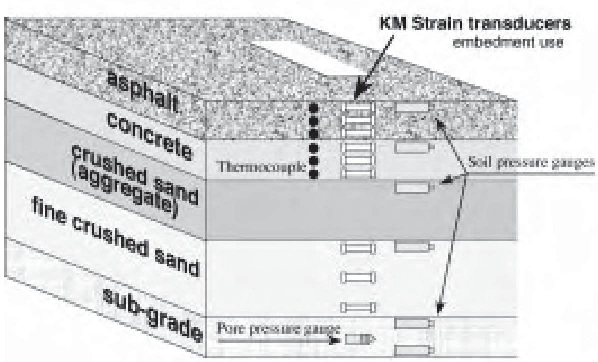
Optional Non-stress meter is available for measurement of the linear thermal expansion coefficient and dry shrinkage strain when a container with the transducer inside is embedded in concrete.

In case that the non-stress meter can not be applied, prepare the same model of concrete specimen to install the meter with the same condition of water inducement during unloaded. And linear thermal expansion coefficient and dry shrinkage strain of concrete can be measured.

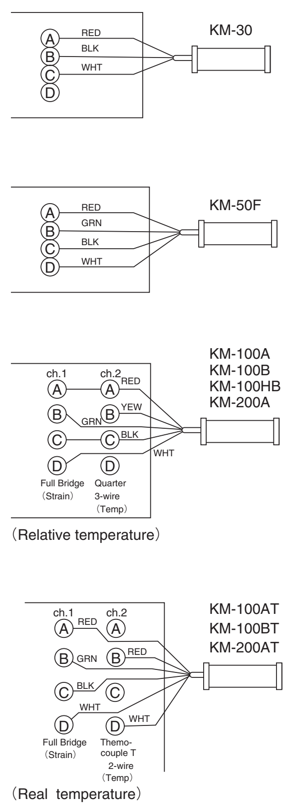
An installation to pavement

During pavement construction, driving tests, loading test, and long-period deterioration tests are conducted using various types of sensors to check the degree of fatigue in relation to the load bearing capcity. The KM measures inner stress produced in each layers under road.

Measuring cables are separately positioned in advance. To protect sensors from mechanical damage, protective cover should be required, and such sensors are temporarily positioned. Then, they are fixed same time in each layer.



■Wiring

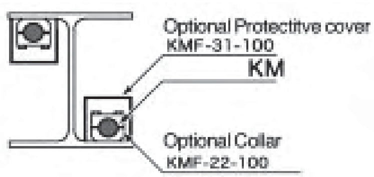


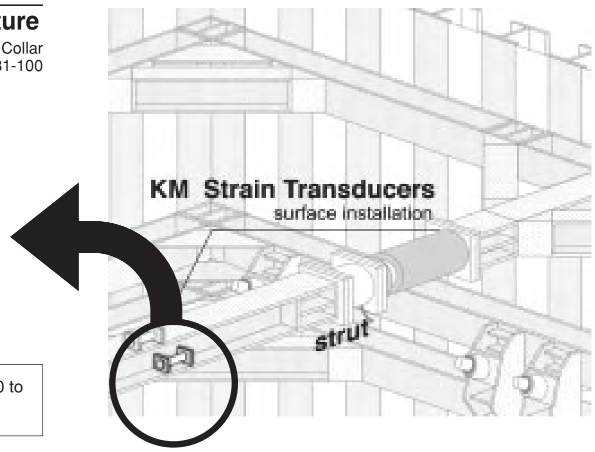
For use of surface strain measurement

Surface strain measurement onto steel and concrete structures is available with KM-100B or KM-100BT. (Optional fittings such as Spacer and Collar are available for fixing the model and positioning gauge length.)

An installation onto surface of steel structure

A strain transducer is installed onto surface of steel using optional Collar KMF-22-100 with welding works. Optional Protective Cover KMF-31-100 protects the transducer from physical damage.

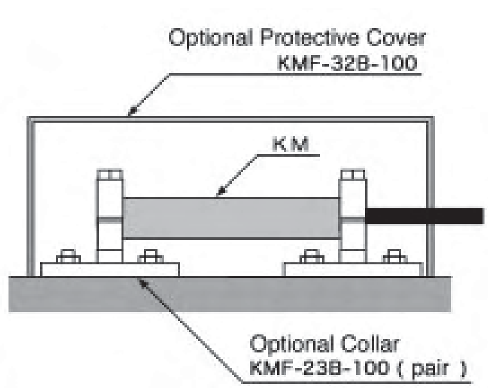




The KM model is combined with optional Collar KMF-22-100 to install onto surface of steel by welding.

An installation onto surface of concrete structure

A strain transducer is installed onto surface of concrete using optional Collar KMF-23B-100 with anchoring works. Optional Protective Cover KMF-32B-100 protects the transducer from physical damage.



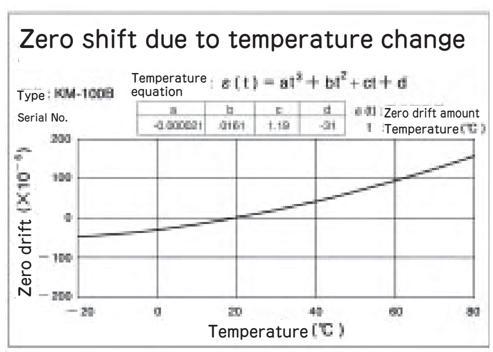
The KM model is combined with optional Collar KMF-23B-100 to install onto surface of concrete structure with anchor bolts.

■Temperature measurement by Strain Transducer

Temperature sensor-integrated strain transducer have 2 types. One is for relative temperature measurement with strain gauge 350Ω quarter bridge with 3-wire system, another is for real temperature measurement with thermocouple sensor. Using Data Logger, it makes more precise measurement possible. Comparing to an external temperature probe use, this model can save considerable installation and wiring works.

Strain gauge temperature sensor integral type
KM-100A/KM-100B/KM-100HB/KM-200A
Thermocouple sensor integral type
KM-100AT/KM-100BT/KM-200AT

Example of Temperature data (optional)



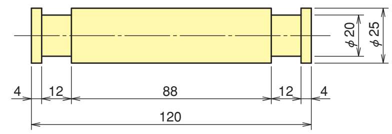
For more precise strain measurement with the transducer, correction of zero shift should be required. Optional temperature data on each supply is available on request.

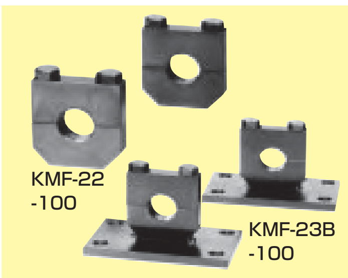
KM Optional accessory

Spacer KMF-12-100

A spacer is needed whenever strain transducer is installed to measure surface strain. The KMF-12-100 spacer is used to accurately locate the gauge length needed to attach KMF-22 and KMF-23B Collars to a structure.

Applicable transducer：KM-100B
KM-100BT

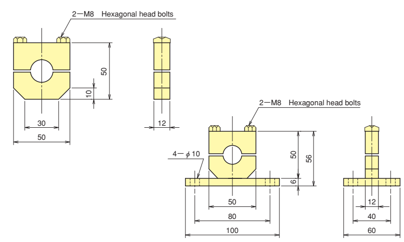




Collar KMF-22-100/KMF-23B-100

The KMF-22-100 Collars are used to mount a strain transducer to steel surface (2 per set), and KMF-23-100 Collars are used to mount the transducer to the surface of concrete (2 per set).

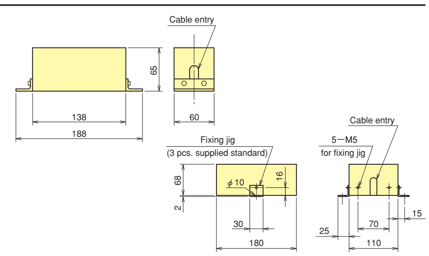
Applicable transducer：KM-100B
KM-100BT



Protective Cover KMF-31-100/KMF-32B-100

The KMF-31-100 protective Cover is used to protect the transducer attached onto steel surface with a KMF-22 Collar, and the KMF-32B-100 is the same onto concrete surface with a KMF-23B Collar.

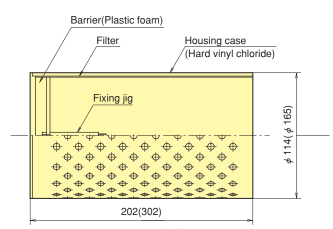
Applicable transducer：KM-100B
KM-100BT



Non-stress meter KMF-51/KMF-52

KMF-51 and KMF-52 are used to measure the linear thermal expansion coefficient and dry shrinkage strain when a container with the transducer inside is embedded in concrete.

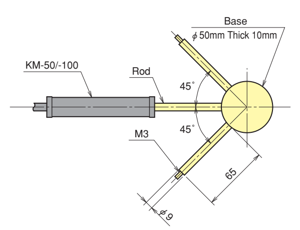
Type	Applicable transducer
KMF-51	KM-100A KM-100B KM-100AT KM-100BT
KMF-52	KM-200A KM-200AT



Spiders KMF-41/KMF-42

KMF-41 and KMF-42 Spiders are used to properly embed the transducer in a predetermined direction for measuring plane and three-dimensional stress in structure.

Type		Axes	Applicable transducer
2-dimensional	KMF-41-2	2	KM-50F KM-100A KM-100AT KM-100B KM-100BT
	KMF-41-3	3	
3-dimensional	KMF-42-3	3	
	KMF-42-4	4	
	KMF-42-5	5	
	KMF-42-6	6	

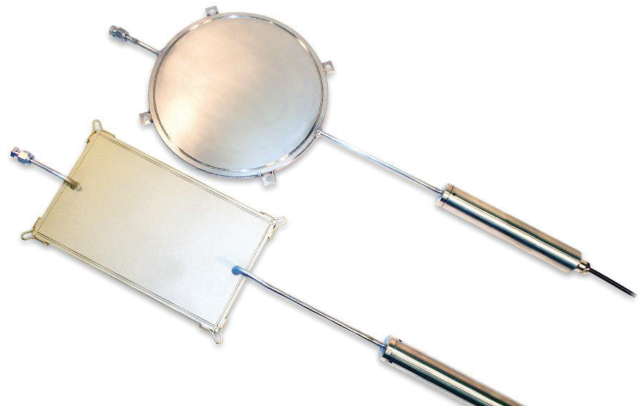


TOTAL PRESSURE CELL
MODEL TPC

GENERAL DESCRIPTION

Total pressure cells are used to measure the total pressure of soil and pore-water acting in the soil mass or structure, for example:

- Embankment dams, to determine magnitude and direction of stresses
- Retaining structures, to determine active and passive earth pressures
- Hydraulically placed fill, to determine densification
- Concrete dams, to measure contact pressure in the foundation and abutments
- Tunnels, to determine stresses on and in tunnel linings



TECHNICAL DESCRIPTION

The TPC cells consist of a sealed distribution pad, composed of two plates welded together around the periphery and filled with de-aired oil. The pad is connected via a length of steel tube to a pressure transducer. Variation in oil pressure resulting from load changes acting on the pad are sensed by the transducer.

The TPC is fitted with a circular or rectangular pad, the latter being designed for measurement or tangential and radial stresses in shortcrete tunnel linings. The stiffness of the TPC is high, enabling its embedment in soil or in concrete. A groove on both sides of the pad increases its flexibility while reducing sensitivity to stress in directions other than normal to the pad face. The concrete stress cell may be fitted with a repressurization tube to restore contact between the pad and the concrete after curing of the latter.

The TPC is fitted with eyelets, to simplify installation, and with a built-in thermistor allowing temperature reading.

FEATURES

- **Long-term reliability**
- **High pressure range**
- **Different types of transducers available: vibrating wire, electrical (4-20mA,0-5Vdc) pneumatic and fiber optic**
- **Rugged stainless steel construction for harsh environments**
- **Easy installation and operation**
- **Compliant with ISRM suggested method**
- **Built-in electrical surge protection**
- **Triple stage water blocking (watertight connector, resin seal and feed through header)**
- **Frequency signal easy to process and transmit over long distances**

SPECIFICATIONS

Range of vibrating wire transducer	200, 350, 500, 750, 1000, 1500, 2000, 3000, 5000, 7000, 10 000, 20 000, 35 000 kPa
Overload	1.5 x F.S.
Construction	Pad with semi-rigid surface and peripheral grooves
Material	Stainless steel
Dimensions of distribution pad	
Thickness	6.3 mm
Circular cell diameter[1]	230 mm
Rectangular cell[1]	100 x 200 mm, 150 x 250 mm, 200 x 300 mm

PRESSURE TRANSDUCER	VIBRATING WIRE	PNEUMATIC	ELECTRICAL	FIBER OPTIC
Pressure range	0-35 000 kPa	0-3500 kPa	0-20 000 kPa	0-20 000 kPa
Accuracy[2]	±0.5% F.S.	±0.25% F.S.	±0.25% F.S.	±0.25% F.S.
Resolution	0.025% F.S. (min)	Depends on Pressure gauge	0.01% F.S.	0.01% F.S.
Thermistor 3kΩ[3] (t° range: -20 to 80°C)	Included	--	Optional	--
Electrical surge protection	Included	--	--	--
Readout unit	MB-3TL	PR-20D	--	FOR-1, UMI
Data acquisition system	SENSLOG	SENSLOG	SENSLOG	FODL
Cable	IRC-41A, IRC-390, CFO-9RF, CFO-3STD			

[1] Other dimensions available upon request.
[2] Calibrated accuracy of the pressure transducer. (+/-0.1%FS with polynomial regression for vibrating wire)
[3] See model TH-T.

ORDERING INFORMATION

Please specify:

- Model and pressure range
- Type of pressure transducer
- Length of electrical cable or tubing
- Length of repressurization tube (1.2 m standard)
- Readout instruments

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NOVA METRIX

BOREHOLE DILATOMETER

Model PROBEX

APPLICATIONS

The PROBEX dilatometer is a radially expandable borehole probe used mainly to determine the short-term deformability of rock in situ. The PROBEX operates in 76 mm (N size) boreholes and has a maximum working pressure of 30 000 kPa. It may also be used to measure the creep properties of materials such as salt or potash. The ease of operation and the reliable method of measurement and interpretation are the direct result of many years of experience with borehole pressuremeters.

DESCRIPTION

The dilatometer test is a loading test run inside a borehole with a radially expandable cylindrical probe.

The PROBEX determines the deformations by measuring the total volume change of the probe. This method is the same well-proven method used with the pressuremeter. It provides a mean modulus value of a large volume of rock, contrary to the use of callipered probes which can be affected by local heterogeneities.

The volume changes of the probe are measured by monitoring the displacement of a piston. This configuration eliminates the parasitic expansion of the tubing and pumping system.

FEATURES

- High capacity
- May be used in deep boreholes
- Test in “N” size boreholes
- Easy to operate

THE PROBEX CONSISTS OF:

- An inflatable membrane mounted on a steel core
- A hydraulic module comprising a dual piston and cylinder assembly, to inflate and deflate the membrane
- A measuring module containing a linear transducer, which monitors the injected volume
- The hydraulic and electrical lead lines
- A hydraulic hand pump and pressure gauge
- A digital readout
- A pressure transducer

TEST AND INTERPRETATION

The leads are threaded inside a BW size casing or equivalent that is used to lower the probe to test depth. For tests in stable shallow boreholes, the probe can be set in place using standard drill rods with the leads fastened to the rod string. The tests are stress controlled. Increments of pressure are applied in stages using the hand pump. The compressibility of the probe is determined by calibration tests ran in a thick-wall cylinder.

The method used to interpret the data is the same one used to reduce pressuremeter data. It is based on Lame's equations and yields a mean modulus of deformation for the rock mass tested.

SPECIFICATIONS

PROBE

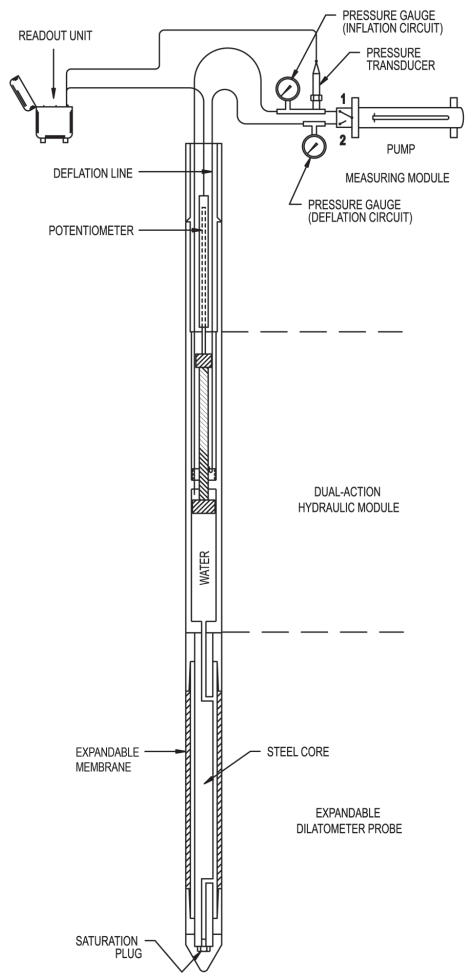
Diameter	
Minimum (deflated)	73.7 mm
Maximum (inflated)	82.5 mm
Loading	
Maximum pressure	30 000 kPa
Nominal length	457 mm

READOUT – MODEL ACCULOG-IX

Function	Volume and pressure indicator
Display	Digital (LCD)
Power Supply	Rechargeable battery pack

RESOLUTION

Diametrical change	1 µm (0.01 cc)
Pressure measurement	0.1% F.S.



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SOFO Deformation Sensor

SOFO

LONG-GAUGE DEFORMATION SENSOR
ROBUST AND TEMPERATURE INDEPENDENT

For surface mounting or embedding in concrete and mortars.
Ideal for long-term structural deformation monitoring.
20 year track record in field applications.

Description

The SOFO deformation sensors are the ideal transducers to monitor large civil structures. Their long-gauge and insensitivity to temperature variations, make them ideal for long-term monitoring of structural deformations. The sensors can be quickly and easily surface mounted or directly embedded in concrete and mortars.

SOFO sensors have been the standard in fiber optic deformation monitoring for the last 20 years.

The sensor is composed of two main parts, an active and a passive one. The active part contains the reference and the measurement fibers and measures the deformations between its two anchors. The passive part is insensitive to deformations and is used to connect the sensor to the Reading Unit. The output is terminated with an E-2000 connector with a built in protective cover.

Key Features

- High resolution
- Embeddable or surface mountable
- Temperature insensitive
- Insensitive to corrosion and vibrations
- No calibration required
- Easy to install
- Long term reliability
- Waterproof
- Static measurements

Applications

- Bridge Structural Health Monitoring
- Building monitoring
- Dam instrumentation
- Tunnel deformation monitoring
- Pipeline local deformation analysis

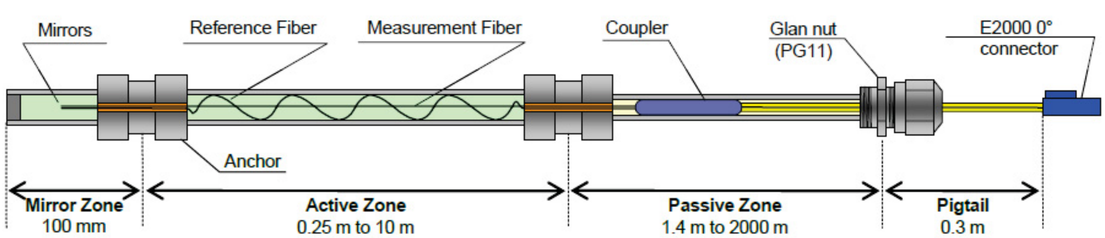
SOFO Deformation Sensor

SOFO

Specifications

Length of active zone (LA, measurement basis)	25 cm to 10 m, standard lengths 10 m to 20 m, customized lengths upon request
Length of passive zone (connecting cable)	1 m to 100 m Customized lengths up to 2000 m upon request
Measurement range	0.5% of LA in shortening, 1% of LA in elongation
Measurement precision	0.2% of the measured deformation or better
Measurement resolution	2 µm RMS
Connecting cable protection options (see specific datasheet for details)	Standard (recommended for embedding or surface mounting in normal conditions) Stainless steel protecting tube (recommended in harsh conditions) Simple cable without protecting tube (recommended for laboratory conditions)
Operating temperature	Standard active zone: -50 °C to +110 °C Special active zone (upon request): -50 °C to +170 °C Passive zone: -40 °C to +80 °C
Waterproof	5 bars (15 bars with extra protection on anchoring points)
Calibration	Not required

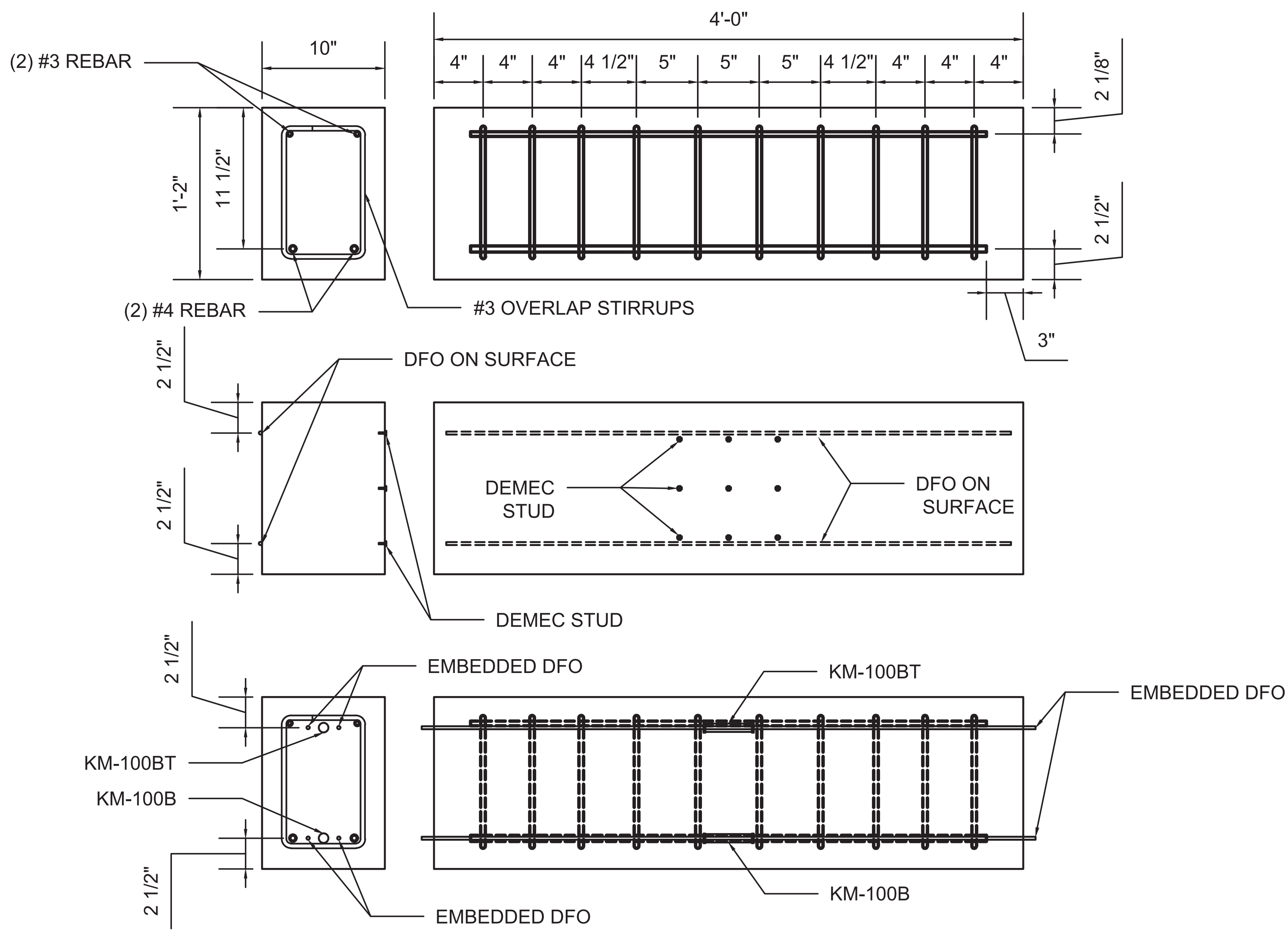
Sensor Configuration



Not to scale

Ordering information

- Length of active zone
- Length of passive zone
- Connecting cable type



NOLAN HAYES	TRIAL SPECIMEN	SHEET 1OF1
ASR	SCALE: 1" = 1'–0"	11/19/15